

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

SPECIFICATION

**INVENTION:** PROCESS FOR ELECTROACOUSTICAL SOUND  
GENERATION IN A MOTOR VEHICLE

**INVENTOR:** Dr. Raymond FREYMAN  
Citizenship: Berberitzenstr. 71b  
Post Office Address/ 80935 München  
Residence: Germany

**INVENTOR:** Dr. Helmut SPANNHEIMER  
Citizenship: German  
Post Office Address/ Boehmerwaldstr. 2  
D-85630 Neukeferloh  
Residence: Germany

**ATTORNEYS:** EVENSON, McKEOWN, EDWARDS & LENAHA, P.L.L.C.  
Suite 700  
1200 G Street, N.W  
Washington, D.C. 20005  
Telephone No.: (202) 628-8800  
Facsimile No.: (202) 628-8844

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TITLE OF THE INVENTION

DEVICE FOR ELECTROACOUSTIC SOUND GENERATION IN A MOTOR  
VEHICLE

BACKGROUND AND SUMMARY OF THE INVENTION

5 This application claims the priority of German application  
19945259.8, filed September 21, 1999, the disclosure of which is  
expressly incorporated by reference herein.

The invention relates to a device for electroacoustic sound  
generation in a motor vehicle.

10 The control of sound in a vehicle component is based on the  
principle that the vehicle occupants should be offered a high  
measure of acoustic comfort, with particular value being attached  
to a low noise level. On the other hand, the driver should also  
be able to exactly recognize the operating state of the engine.  
15 For this purpose, feedback of the driving sound, particularly  
feedback of the engine sound, is advantageous. In other respects,  
emission regulations (including noise emission regulations) must  
be met.

20 To resolve these conflicting aims it is known in the art to  
modify the noise in the passenger compartment by passive  
adjustment measures, e.g., by aggregate bearings.

Furthermore, in addition to good sound insulation, the synthetic generation of passenger compartment sounds, or the storing of sound components and electroacoustic playing into the passenger compartment, are also known in the art (cf. European Patent EP 0 469 023 B1, German reference DE 27 34 948 A1).

The exhaust system and the intake tract are sources which have strong load dependency. However, a general increase in the sound emitted by these excitation sources is not an appropriate solution due to the aforementioned emission and external noise regulations. Additionally, the introduction of these sound components into the compartment is largely inhibited by high body insulation, which is necessary to reduce wind and rolling sounds and to suppress interfering mechanical engine sound components. Although a deliberate mechanical introduction into the passenger compartment is possible in principle and known in the art (German references DE 44 35 296 A1, and DE 42 33 252 C1), it has proven to be disadvantageous with respect to costs and arrangement within the vehicle.

A purely synthetic production of an engine sound has also proven to be disadvantageous since, as a rule, it does not give the perception of an absolutely authentic engine sound.

German Patent DE 198 45 736 A1 therefore proposes to detect the sound pressure in the intake or exhaust tract of an internal

combustion engine, to process it and to introduce the signals thus generated into the passenger compartment. The intake and exhaust tracts are acoustic sources that are particularly load-dependent. Even very simple embodiments can thus convey relatively faithful acoustic signals to the passenger compartment. Using filtering elements in a signal processing unit of the above-described device allows for variation in the sound characteristic. There are limits, however, with respect to this ability to modify the sound composition. For example, those frequency spectrums that are not contained in the signals supplied by the sound pressure sensor cannot be generated.

Thus, the object of the present invention is to improve an initially described device for electroacoustic sound generation in such a way as to ensure a sound generation that is as variable as possible but nevertheless authentic.

Accordingly, a synthesizer is added to a device such as the one disclosed by DE 198 45 736 A1. This synthesizer artificially produces signals or sounds and adds these sound components to the signals generated from the sound pressures. This makes it possible to introduce sounds into the passenger compartment with frequencies that do not occur in the intake or exhaust tracts.

To produce a particularly authentic engine sound, it was found to be advantageous to generate sinusoidal frequencies that

can be traced to the rotational frequencies of the driving engine. In particular, one or several sinusoidal frequencies corresponding, for example, to a half-integral and/or integral multiple of the engine speed can be generated.

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Adding synthesized sound components to the sounds that are generated via the sound pressure sensor makes it possible to produce an overall impression that is desirable from the perspective of a sound designer and still sounds authentic.

10 In one embodiment amplitudes and phases of sinusoidal frequencies are first stored. These amplitudes and phases are added in a table as a function of the rotational speed of the driving engine. Depending on the engine speed, the corresponding amplitude and phase values can be read out of the table, and the synthesizer can generate signals as a function thereof. This makes it possible to achieve a sound characteristic that is adapted to the speed. Of course, the amplitude ratio of the various pure tones decisively determines the overall sound characteristic. The amplitude of the signals to be played by the  
15 synthesizer can also be influenced by, for example, the throttle position, the accelerator pedal position, or other load signals. Particularly by taking into account signals that are coupled to a load, it is possible to achieve load-dependency of the  
20 generated sound as well.

According to an alternative embodiment, the signal from the sound pressure sensor itself can serve as the input variable for the synthesizer. This input signal is also load-dependent in a particular manner.

5 If a certain sound characteristic is to be achieved as a function of different vehicle operating conditions, the amplitude and/or phase ratios of the individual sounds must be modified. In addition to control via the throttle position, the accelerator pedal, the rotational speed of the driving engine, and the vehicle speed, other parameters, such as the kickdown position, gear selection or, for example, a signal indicating whether the convertible top is open or closed can be used to determine the amplitude and/or phase ratios. Several tables can be provided from which values can be selected as a function of these or other vehicle parameters.

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20 In a particularly advantageous embodiment, push operation is detected and a matching sound is created. For example, during the transition to push operation, a slowly surging sound can be produced. It is also possible to produce a stochastic noise during push operation (putt-putting, muttering) and play. To this end a unit to detect push operation must be provided. Depending on the evaluation signal, a characteristic acoustic pattern must then be selected for this push operation and a signal must be

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supplied to the synthesizer. The synthesizer then produces a  
desired sound in push operation.

Overall, the present invention provides a further  
improvement of the sound in a passenger compartment, particularly  
5 in view of the variability with respect to different vehicle  
operating conditions.

Other objects, advantages and novel features of the present  
invention will become apparent from the following detailed  
description of the invention when considered in conjunction with  
10 the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The single figure is a sketched schematic diagram of an  
exemplary embodiment of the device according to the invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

15 In an intake tract of a motor (not depicted), a sound  
pressure sensor 12 is provided, which detects the changes in air  
pressure produced by the vehicle dynamics and supplies them to  
a signal processing unit 14. Alternatively, the sound pressure  
sensor can also be arranged in the exhaust tract, or near the

intake or exhaust tract, e.g. in the area of the intake tract inlet or the exhaust tract outlet.

The signal processing unit 14 processes, among other things, the signals from sound pressure sensor 12 and supplies them to a loudspeaker unit 16 that transforms the signals generated by signal processing unit 14 into acoustic signals and plays them into the passenger compartment. The loudspeakers used can be separate loudspeakers or the loudspeakers of an already existing audio or communications system of a vehicle.

Signal processing unit 14 in the present case essentially comprises two branches. On the one hand, the signal originating from sound pressure sensor 12 is processed in a filter unit 20, 22, 24, 26, which will be further described below, and, after corresponding amplification, is supplied to loudspeaker unit 16. In a second branch, signals corresponding to sound components are synthesized and added to the signals originating from sound pressure sensor 12. This procedure makes it possible to produce an authentically sounding passenger compartment sound that can be varied in any manner over a wide range.

In the first branch, the signal from sound pressure sensor 12 is first sent through a high-pass filter 20 to eliminate low frequency sound components that would result in excessive membrane movements. The signal supplied by high-pass filter 20



is split into two paths. In one path, the signal is guided through a low-pass filter 22 and then to a potentiometer 26 which, depending on its adjustment, supplies a more or less attenuated signal to an adder 27. The adjustment of the potentiometer is determined via input variable E, which will be further explained below. Of course, other embodiments can use other filter arrangements in the different branches.

The signal in the other path of the first branch goes directly to a further potentiometer 24 and thus has broadband components. After potentiometer 24, this signal is also supplied to adder 27. The two signals coming from potentiometers 24 and 26 are brought together and added in the adder 27 (mixed).

In the second branch, the synthetic branch, a synthesizer 40 is provided, which is designed to produce sinusoidal frequencies. Synthesizer 40 in the present embodiment has an input to which the rotational speed signal N of the driving engine is supplied. As a function of this rotational speed signal N, synthesizer 40 produces several pure tones, the frequencies of which correspond to half-integral and integral multiples of the engine speed. The amplitudes and phases of the respective sinusoidal frequencies depend on the engine speed and are read out of a memory unit 42. For this purpose, synthesizer 40 supplies the rotational speed signal to memory unit 42. Memory unit 42 has at least one table in which the amplitudes and phases

are stored as a function of the engine speed. Based on the quantities read out of the table and memory unit 42, synthesizer 40 generates a signal with a certain sound characteristic. Of course, the amplitude ratio, the phase position and the number of pure tones determine this sound characteristic. The signal generated by synthesizer 40 is supplied to a further potentiometer 44, which defines the signal intensity.

The signal for synthetic sound generation is added by adder 46 to the signal from the sound generation via the sound pressure sensor. The overall mixture, in the present case, is determined by the adjustment of potentiometers 24, 26, 44.

The total signal is subsequently guided through a further low-pass filter 28 so that the frequencies are upwardly limited.

Alternatively, the signal of each path can be guided through a low-pass filter of its own and be mixed in an adder positioned after these low-pass filters. At this location of the arrangement it is furthermore possible to provide an equalizer filter with which the transmission behavior of the loudspeaker or the passenger compartment can be influenced.

Finally, the signal thus processed is amplified in an amplifier 30 and supplied to loudspeaker unit 16 of the vehicle. The loudspeaker unit transforms the electric signal into an

acoustic signal. This results in a signal in the passenger compartment, which is very authentic but varied in the desired manner.

In the present case, potentiometers 24, 26 and 44 are manually adjusted. By a change in the corresponding potentiometers, the weighting of the respective paths can be changed between a broadband and low-band component of the signal coming from the sound pressure sensor on the one hand and the synthetic signal on the other hand. The setting of the potentiometers can also be fixed.

Alternatively, the potentiometers can be electronically controlled and can depend on the vehicle operating conditions. The figure shows corresponding signal inputs E by which this adjustment can be made. For example, potentiometers 24, 26 and 44 can be adjusted as a function of the throttle position, the rotational speed signal of the driving engine, or the speed. For this purpose, signal processing unit 14 can be connected to a CAN bus and be provided with an additional control unit which controls potentiometers 24, 26 and 44.

In a further alternative embodiment - indicated by the dashed line representing the input variables of synthesizer 40 - other vehicle operating parameters can be used to generate and/or control the synthetic signal. For example, the number of

pure tones, the decision whether half-integral and integral multiples of the engine speed frequencies are used, and the amplitude and phase ratios can be made a function of input variables, such as throttle position, accelerator pedal position, vehicle speed and engine speed. Among the input variables K, other parameters, such as kickdown position, gear selection, or a signal indicating whether the convertible top is opened or closed, can also be read in. Overall, the same parameters can be used for both input variables E and K. Depending on the embodiment of the synthesizer and the consideration of different input parameters, it is possible to achieve specially adapted, dynamic sound impressions. It is also possible to store several tables in memory unit 42, which are read out as a function of the input parameters. The sound to be played into the passenger compartment can thus be varied over a wide range, without excessively deviating from the authenticity of the sound from the intake area.

Taking into account the signal from the sound pressure sensor in synthesizer 40 (see the corresponding dashed line in the drawing) has proven to be particularly advantageous. By controlling the sound characteristic and the dynamics via the signal from sound pressure sensor 12, a special change with respect to load dependency can be achieved.

The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

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